Raytheon

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SYSTEM DEFINITION FOR CONVERTIBLE ENROUTE/PRECISION DISTANCE MEASURING EQUIPMENT FINAL REPORT

Prepared for:

The Transportation Development Centre

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Un sommaire en français de ce rapport est inclus avant la Table des matières.

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17. Abstract

This report presents the system definition for a convertible Distance Measuring Equipment (DME) capable of both enroute and precision applications (DME/N and DME/P). The definition is presented in terms of system and module specifications and block diagrams. The block diagrams indicate that a high degree of commonality is achievable between the two types of DME. With the exception of the final RF power amplifier in the DME/N, the system hardware configuration is identical for both systems. In order to achieve high reliability and, for MLS operation, a fast changeover response time, the system architecture makes use of parallel redundant modules, enabling the system to function in a majority of situations where more than one module has failed. A cost benefit study, Attachment A, compares the costs of a convertible DME, designed and built by a single manufacturer to separate DME/N and DME/P equipment provided by different suppliers. The findings show that the purchase and operating cost of separate DME systems are typically 34% greater than for the convertible system. The report includes a timing analysis, Attachment B, that identifies and quantifies error contributions from various sources in the ground based equipment. This report concludes the first phase of a three phase program to produce a prototype convertible DME. Phases 2 and 3 of the program involve design and testing of a convertible transponder and a prototype single-channel system. Cost estimates for these phases are provided in Attachment C.

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17. Résumé

Ce rapport traite de la définition d'un DME (appareil de mesure des distances) à niveaux de précision, un normal (type DME/N) et un haute précision (DME/P). Le devis descriptif présente les caractéristiques du DME convertible dans son ensemble et de chaque module en particulier, et en donne les schémas de principe. Ces schémas montrent qu'un degré de banalisation élevé peut être réalisé à l'égard de ces deux types de DME car, exception faites de l'amplificateur RF de l'étape finale du type N, ils sont identiques côté matériel. Afin de réaliser une fiabilité élevée, et en exploitation MLS, un temps de conversion rapide, le DME décrit comporte des modules redondants parallèles qui lui permettent de continuer à fonctionner dans la plupart des cas, malgré la défaillance d'un module ou plus. Dans l'étude avantages/coût présentée à l'annexe A, un DME convertible d'une même provenance est comparé à un ensemble formé d'éléments N et P de provenances diverses. Il a été constaté que, dans ce dernier cas, les coûts d'acquisition et d'exploitation étaient en général supérieurs de 34 p. 100 à ceux de premier. Le rapport présente, en outre, une analyse des temps de réponse (annexe B) qui a permis de détecter et de quantifier les erreurs attribuables à divers éléments de l'équipement au sol. Le rapport met fin à la première étape d'un programme en trois phases visant la réalisation d'un prototype de DME convertible. Quant aux phases 2 et 3, elles concernent l'étude et l'essai d'un transpondeur convertible et d'un prototype de DME monocanal. Les devis estimatifs correspondants sont donnés dans l'annexe C.

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SUMMARY

This report presents the system definition for a convertible distance measuring equipment (DME) capable of both enroute and precision applications (DME/N and DME/P). The definition is presented in terms of system and module specifications and block diagrams. The block diagrams indicate that a high degree of commonality is achievable between the two types of DME. With the exception of the final RF power amplifier in the DME/N, the hardware configuration is identical for both systems. In order to achieve high reliability and, for MLS operation, a fast changeover response time, the convertible system makes use of parallel redundant modules, enabling the system to function in the majority of situations where more than one module has failed. A cost benefit study (Attachment A) compares a convertible DME, designed and built by a single manufacture, to separate DME/N and DME/P equipment provided by different suppliers. The findings show that the purchase and operating costs of separate DME systems are typically 34% greater than for the convertible system. The report includes timing analysis (Attachment B) that identifies and quantifies error contributions from various sources in the ground-based equipment. This report concludes the first phase of a three-phase program to produce a prototype convertible DME. Phases 2 and 3 of the program involve design and testing of a convertible transponder and a prototype single channel system. Cost estimates are provided in Attachment C.

SOMMAIRE

Ce rapport traite de la définition d'un DME (appareil de mesure des distances) à niveaux de précision, un normal (type DME/N) et un haute précision (DME/P). Le devis descriptif présente les caractéristiques du DME convertible dans son ensemble et de chaque module en particulier, et en donne les schémas de principe. Ces schémas montrent qu'un degré de banalisation élevé peut être réalisé à l'égard de ces deux types de DME car, exception faites de l'amplificateur RF de l'étape finale du type N, ils sont identiques côté matériel. Afin de réaliser une fiabilité élevée, et en exploitation MLS, un temps de conversion rapide, le DME décrit comporte des modules redondants parallèles qui lui permettent de continuer à fonctionner dans la plupart des cas, malgré la défaillance d'un module ou plus. Dans l'étude avantages/coût présentée à l'annexe A, un DME convertible d'une même provenance est comparé à un ensemble formé d'éléments N et P de provenances diverses. Il a été constaté que, dans ce dernier cas, les coûts d'acquisition et d'exploitation étaient en général supérieurs de 34 p. 100 à ceux de premier. Le rapport présente, en outre, une analyse des temps de réponse (annexe B) qui a permis de détecter et de quantifier les erreurs attribuables à divers éléments de l'équipement au sol. Le rapport met fin à la première étape d'un programme en trois phases visant la réalisation d'un prototype de DME convertible. Quant aux phases 2 et 3, elles concernent l'étude et l'essai d'un transpondeur convertible et d'un prototype de DME monocanal. Les devis estimatifs correspondants sont donnés dans l'annexe C.

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Under Separate Cover:

Attachment A: Cost Benefit Study for a Convertible DME/N & DME/P

Attachment B: Timing Analysis for DME/N & DME/P Equipment

Attachment C: Phase 2 & 3 Cost Estimates for a Convertible DME/N & DME/P

1. Introduction

This Final Report for the System Definition of a Convertible DME/N and DME/P has been prepared as a part of:

DSS Contract No. T8200-6-6532/01-SD.

This System Definition Contract was for the first phase of a three phase program for the development of a Convertible DME/N and DME/P designed to satisfy Transport Canada requirements for Enroute and Precision DME equipment. The second and third phases are for the continued development of a Convertible DME design to produce a Feasibility Demonstration of essentially the Transponder for Phase 2 and an Engineering Model of the equipment for Phase 3.

Raytheon Canada Limited has manufactured Navigation Aid equipment for over 25 years. Specifically the Raytheon Enroute Distance Measuring Equipment(DME/N) was designed and manufactured in 1970 for Transport Canada. Since that time over 140 DME/N equipment units have been built for Canadian and international customers. Because of the need for precision DMEs, for use with the Microwave Landing Systems(MLS), and the upgrading of the ICAO specifications for DME/N, new designs of both types of equipment will be necessary to meet Transport Canada requirements. Also because of the many similarities between DME/N and DME/P equipment it is Raytheon Canada's contention that the next Transport Canada procurements of DME should be for a design that can be easily adapted for use as either a DME/N or a DME/P, a convertible DME/N and DME/P. The advantages of a convertible DME system are in reduced hardware and software design costs and in the reduction of the logistics requirements.

The purpose of this study is to define a Convertible DME, in terms of system specifications, block diagrams and module specifications, and to prepare a cost benefit analysis to show the cost advantages of the Convertible DME approach versus that of a DME/N and DME/P procured from different suppliers.

1.1 Data Package

The full documentation associated with this Report includes the following specifications and drawings:

*	G171382	DME/N/P Overall Block Diagrams
*	RCL 4015	DME Modulated Power Amplifier
	RCL 4239	Specification for DME/N and DME/P Navaid Systems
	RCL 4242	Directional Coupler Specification
	RCL 4243	Preselector Assembly Specification
	RCL 4244	Circulator Specification
	RCL 4245	Antenna Transfer Switch Specification
	RCL 4246	RF/IF Amplifier Design Specification
	RCL 4247	Log IF/Video Module Design Specification
*	RCL 4248	Transponder Signal Processor Hardware Design Specification
	RCL 4252	Dummy Load Unit Specification
	RCL 4254	Local Oscillator Select Switch Specification
	RCL 4256	ISG RF Transfer Switch Specification
	RCL 4259	RF Exciter and Local Oscillator Specification
*	RCL 4262	Monitor Main Processor Hardware Specification
*	RCL 4263	Monitor Signal Processor Hardware Design Specification
	RCL 4264	Monitor RF Unit Specification
	RCL 4265	Data unit Design Specification
	RCL 4266	Interrogation Signal Generator Design Specification
	RCL 4267	Local Control and Status Unit Specification
	RCL 4268	RF Coaxial Switch Specification
	RCL 4271	Circulator Unit Specification
	RCL 4274	Coaxial Attenuator Specification
	RCL 4341	Convertible DME/N and DME/P Block Diagram Description
	RCL 4342	DME/N/P Specification for Transport Canada
*	RCL 4343	Transponder/Monitor Signal Processor Software Specification
*	RCL 4344	Monitor Main Processor Software Specification

Note: Items marked with an asterisk are proprietary and identified as such per Section S36(vi) of the Contract.

2. Cost Benefit Analysis

Attachment A, provided under separate cover, is a detailed Cost Benefit Analysis of the Convertible DME from one supplier versus non-convertible DME/N and DME/P from different suppliers.

in summary the cost benefit study shows that there are considerable cost reductions to be achieved through adopting a planned approach to the procurement of DME/N & DME/P. In particular, depending upon quantity and life cycle span, purchase and operation of convertible DME/N & DME/P equipments will be cheaper by approximately $6 million to $9 million. For example, over 5 years, for quantity 20 each of DME/N and DME/P, the purchase and operation of these equipments from different manufacturers is more costly by $6.1 million, or by 34%, over that of a convertible equipment from one manufacturer.

Refer to Attachment A for full details of the analysis.

3. System Design for the Convertible DME/N/P

The system design approach develops a Convertible DME system for either DME/N or DME/P applications. The definition of Convertible DME is a DME which by replacement, or removal or addition of a minimal quantity of unique modules will fulfill the function of either an Enroute DME (DME/N) or a Precision DME (DME/P). The proposed convertible system design provides for a DME final configuration which is field reconfigurable to either a DME/N or DME/P as required. The system design provides a high degree of commonality among the modules and other components for both systems. The System Design is broken down into various elements as shown in the following paragraphs.

3.1 Draft DME/N/P Specification for Transport Canada

RCL 4342 has been prepared as a draft version of the DME/N/P specification, and is included in the data package. This specification defines the functional and technical requirements for a Convertible DME/N and DME/P equipments. The specification does not include EIU, RMMS and MLS functional and interface requirements. The Convertible DME design does include a standard interface from the Monitors and Control Unit to provide the necessary interface to an RMMS.

3.2 Block and Level Diagrams

Data Package drawings G171382 are a set of Block and Level Diagrams which describe the proposed Convertible DME/N or DME/P. Figure 1 shows the block diagram in summary form. In the diagram the three configuration switches are, for clarity, shown as common units. In fact they are part of the unit which follows, thus they are considered redundant. As can be seen from the diagram the system is configured as a parallel unit redundant system. The main feature of the parallel redundant system is its capability to operate with two and more failed modules of differing types. This compares to the Main/Standby approach which shuts down after any two failures. Thus a parallel redundant system will provide higher system availability to that of the Main/Standby system and will therefore reduce maintenance costs. This is particularly true of Enroute DME which are usually located at remote sites. For the Precision DME, a site visit following a single failure will be necessary in order to meet the Final Approach(FA) requirements of higher categories of operations.

A complete description of the system diagrams is given in RCL 4341.

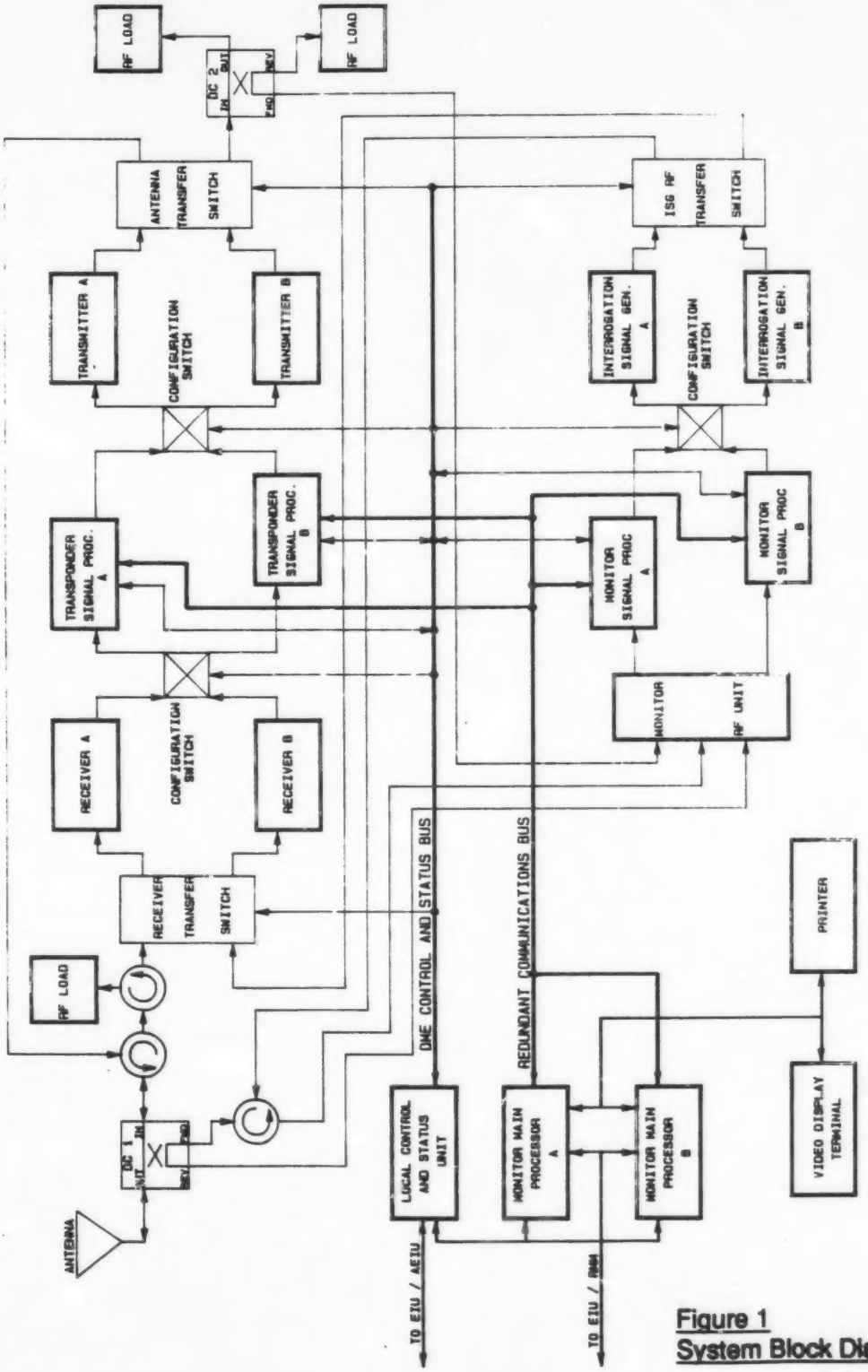

Figure 1
System Block Diagram

3.3 Timing Analysis

Attachment B, provided under separate cover, presents a timing analysis of both DME/ N & DME/P equipment. The timing analysis describes and quantifies the error contributions. A summary of these factors is as follows:

Signal-to-Noise Ratio of Demodulated Received Pulses
Stability of Time-interval Clock Frequency
Quantization Error of Time Measurement
Trigger Error
Log IF Amplifier Characteristics Error
Pulse Shape Error (reply pulse)

The analysis shows that the main contributors to the transponder error are the Log IF amplifier characteristics and the signal-to-noise ratio of the demodulated received pulses. These error sources, even for high precision circuit designs, are problems to the accuracy of both DME/N and DME/P types of equipment. It is suggested that the solution to the problem is to linearize the Log IF characteristics to correct the timing of the received pulses based upon their measured amplitudes using an automatic calibration loop under software/firmware program control.

3.4 DME/N & DME/P Modules

The Convertible DME comprises the following modules:

Antenna Transfer Switch
Attenuator Coaxial
Circulator (20dB)
Circulator (40dB)
Data Unit
Directional Couplers (Qty 2)
DME/N Antenna
DME/N Power Amplifier & Modulator
DME/P Antenna
DME/P Power Amplifier & Modulator
Dummy Load Electrical (Qty 2)
Interrogation Signal Generator
ISG RF Transfer Switch
Local Control & Status Unit
Local Oscillator Select Switch
Log IF/Video Module

Monitor Main Processor
Monitor RF Unit
Monitor Signal Processor
Power System
Preselector Assembly
Receiver Transfer Switch
RF Exciter and Local Oscillator
RF/IF Amplifier
Transponder Signal Processor

3.5 Modules Specifications

With the exception of the Antennas, module specifications have been developed for the modules listed above and are included with the data package. For further details refer to paragraph 1.1.

3.6 System Performance Monitoring

In the proposed design, it is intended to make the use of VDT/Keyboard to provide the visual means of monitoring the system status and controlling the system.

3.7 Microprocessor Technology

During the system design the use of microprocessor technology was a major consideration. Currently the design includes the use of microprocessors in Transponder Signal Processors, Monitor Signal Processors and Monitor Main Processors.

4. Phase 2 Tasks, The Feasibility Demonstration

4.1 Design Tasks

For Phase 2 the tasks are split as follows:

System Engineering
Hardware Development
Software Development
Integration and Testing

The system engineering aspects include the following design tasks:

System Segment Specification
System Interface Control Documents
Establish System H/W and S/W performance requirements
System Top-Level Data Flow Diagram
System Data Dictionary
System Design Review data packages.
Design Reviews.
Maintain Block & Level diagrams.
Reliability Plan
System Test Plan.

The hardware design tasks include the design and breadboard of those modules which are to be considered as essential to show that the proposed system is viable. Accordingly the modules are:

DME/N Power Amplifier & Modulator
DME/P Power Amplifier & Modulator
Log IF/Video Module
RF/IF Amplifier
Transponder Signal Processor

Interrogation Signal Generator
Monitor Signal Processor

The first five modules form the basis of a Convertible Transponder, the last two modules are considered necessary to test the Transponder.

The engineering activity for each module includes the generation of the following documentation:

Block and schematic diagrams.
Parts List.
Artwork layout sketches.
Reliability calculation.
Test data.
Design Review Data package

The software will be developed for the Transponder Signal Processor and some test software for the Monitor Signal Processor.

The integration and test tasks include software integration on the two signal processors, the integration and test of the Transponder and the demonstration of the Phase 2 equipment.

4.2 Phase 2 Estimates

Estimates for the Phase 2 tasks were prepared for both future development work and cost benefit evaluation. The estimates are provided under separate cover as Attachment C.

5. Phase 3 Tasks, The Engineering Model

5.1 Design Tasks

For Phase 3 the tasks are split as follows:

System Engineering
Hardware Development
Software Development
Integration and Test

The system engineering aspects are for the completion of the system documentation for all the DME modules, as follows:

System Segment Specification
System Interface Control Document.
System Hardware/Software Performance Requirements.
Complete System Data Flow Diagram
Update System Data Dictionary
System Design Review data packages.
Conduct Design Reviews.
Maintain Block & Level diagrams.
Reliability Plan update.
System Test Plan.

The hardware design tasks are to complete the design tasks and build one channel of a dual channel capable, engineering model, of a Convertible DME/N and DME/P suitable for Design Approval Testing (DAT). The documentation to be produced by engineering is as follows:

Block and schematic diagrams.
Parts List.
Artwork layout.
Assembly Drawings.
Reliability calculation.
Test data.
Design Review Data package

This documentation is for all of the modules required for a Convertible DME/N & DME/P, except for the RMM/EIU and the antennas.

The software will be developed for the Monitor Signal Processor and the Monitor Main Processor.

The test tasks include software integration of the Monitor Signal Processor, the Monitor Main Processor, the integration, the test of the completed single channel DME both as a DME/N and a DME/P and the demonstration of the Phase 3 equipment.

5.2 Phase 3 Estimates

Estimates for the Phase 3 tasks were prepared for both future development work and cost benefit evaluation. The estimates are provided under separate cover as Attachment C.

6. Conclusion

The objective of specifying a DME which can be converted from DME/N to a DME/P and vice versa, using a small number of mission specific modules, has been achieved.

The system is specified sufficiently to determine estimates for follow-on development.

The feasibility of producing a cost effective design has been proven and a set of module specifications developed.

Design Estimates have been produced for the following:-

Phase 2, The Feasibility Demonstration.
Phase 3, The Engineering Model.

The benefit of contracting a Convertible DME/N/P from one supplier has been modeled and for all scenarios shows a clear advantage over designs/procurements from different suppliers. This advantage is expected to exist even if Transport Canada specifications will permit the procurement of off-the-shelf DME to help minimize the non-recurring element (NRE).

That economics of scale can have a significant effect by combining the procurement quantities required for Enroute and MLS operations.

7. Recommendations

That in the interests of economy, consideration be given to a joint procurement of Convertible DME/N and DME/P equipments from one supplier.

Because of a follow-on international market for both DME/N and DME/P it is important to maximize capability to compete. This can be optimized through the Convertible DME concept.

That follow-on development phases be funded to achieve the following objectives:

Phase 2: Complete a Transponder and reduce risk by testing hardware and demonstrating software calibration techniques.

Phase 3: Establish a manufacturable "build" configuration that can meet Transport Canada and international requirements for both performance and cost.

8. References

1. CAA Paper 79013. "Precision Distance Measuring Equipment (PDME)" For Use with MLS," Civil Aviation Authority London, August 1979.

2. Hirsch Charles J. "L-Band MLS/DME Compatible with ICAO Annex. 10, Automation Industries Inc., Vitro Laboratories Division, October 26, 1975.

3. Department of Transportation, Federal Aviation Administration Specification, FAA-E-2721/3b, "Microwave Landing System Ground Equipment, Precision Distance Measuring Equipment (DME/P), October 27, 1983.

4. International Civil Aviation Organization, AWOP working group and panel meeting papers and minutes.

5. International Civil Aviation Organization, International Standards Recommended Practices and Procedures for Air Navigation Services, Aeronautical Telecommunications, Annex 10, Vol. 1., Fourth Edition, April 1985.

6. Kelly. R.J., "System Considerations for the New DME/P International Standard," IEEE Trans. on Aerospace and Electronic Systems, Vol. AES-20, No. 1., January 1984.

7. Kelly. R.J.and LaBerge. E.F.C.,"Guidance Accuracy Considerations for the Microwave Landing System L-Band Precision DME," The Bendix Corporation, Communication Division, Baltimore. Maryland. May 1979.

8. Vogel. H., "Precision DME for Future Landing Systems:One Solution," Electrical Communication, Vol. 51, No. 4., 1976

9. Glossary of Terms

ADS	Automatic Delay Stablization
BLD	Block and Level Diagrams
CMN	Control Motion Noise
CSC	Computer Software Component
CSCI	Computer Software Configuration Item
DAT	Design Approval Test
DME	Distance Measuring Equipment
DME/N	Distance Measuring Equipment, Enroute
DME/P	Distance Measuring Equipment, Precision
DME/N/P	Distance Measuring Equipment, Enroute, Precision
DSI	Deliverable Source Instruction
DSS	Department of Supply and Services
DU	Data Unit
EIU	Equipment Interface Unit
ERP	Effected Radiated Power
FA	Final Approach
IA	Initial Approach
ICAO	International Civil Aviation Organization
IF	Intermediate Frequency
ILS	Instrument Landing System
ISG	Interrogation Signal Generator
LOG	Logarithmic
MLS	Microwave Landing System
MMP	Monitor Main Processor
MSP	Monitor Signal Processor
MSS	Main/Standby System
NRE	Non-Recurring Elements
PFE	Path Following Error
PURS	Parallel Unit Redundant System
RF	Radio Frequency
RFP	Request For Proposal
RMMS	Remote Maintenance and Monitoring System
RSS	Root Sum Square
TDC	Transportation Development Centre
TIE	Transponder Instrumentation Errors
TOA	Time-of-Arrival
VDT	Video Display Terminal
XPDR	Transponder
XSP	Transponder Signal Processor